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MODEL-ORIENTED METHOD OF DESIGN IMPLEMENTATION WHEN CREATING DIGITAL FILTERS

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Abstract: This article discusses the example of model-oriented method of design and development of digital low-pass filters (LPF) for automatic control systems (ACS). Typically, high frequency noise and disturbance attenuation is carried out by analogue LPF. However, technical implementation of analogue filters higher than the second order arouse certain difficulties related with the need of precise passive components ratings selection (resistors, capacitors). If the noise and disturbances spectral composition is known, it is possible to build digital LPF with the Nyquist frequency greater than the maximum frequency in the noise spectrum. Such possibility has appeared because of cheap, energy-efficient, high-speed 32-bit microcontrollers market entry. They have analogue signals sampling rate of 30 kHz and above. The traditional approach using the "manual" method of filter parameters calculation, obtaining their recurrence expressions and further program implementation requires high qualification and a lot of time consumption from the developer. An alternative to this approach is the model-oriented method of design (MOMD) in MatLab environment when in the one environment the design of digital LPF, verificaton of its performance as a part of the ACS, generation and compilation of program codes for selected microcontroller family take place. MOMD can also be used in the designs of bandpass and bandstop filters for adaptive control systems or systems of technical diagnostics. If during the commissioning or the operation of ACS there is a need in digital LPF parameters change then this operation can be performed within half an hour. MOMD technology allows to significantly reduce the time for developing a specific product without loss of quality in its design 'cause of extensive possibilities of MatLab development environment.

Key words: Model-oriented method, design, development, filtration, automatic control systems, core ARM Cortex M4, STM32F4 discovery.

Introduction

It is known as a fact that ACS is capable of external disturbances impacts consequences compensation if their frequencies don't exceed ACS Nyquist frequency. More higher frequencies, measurement noises, electromagnetic pickups, which occur during signal transfers from sensor to controller, must be filtered with analogue low pass filters [1]. However, technical implementation of analogue filters which are higher than second order cause difficulties related with the need of precise passive components ratings selection (resistors, capacitors). If during implementation of the system arouse the necessity to change the parameters of the analogue filter than time consumptions for this procedure would be comparable to time consumptions for design and development of the new filter. Digital LPF can be implemented as a program in controller, but we must take into account that the sample rate of the controller is within range of $F_s=10$ Hz and, accordingly, such filter would be capable of disturbances attenuation with frequency below $F_s/2=5$ Hz. The attempt to filter the disturbances of industrial frequencies only with this filter would result in origin of frequency translation effect of the disturbance in the low-frequency range. In this case it would be impossible to separate the disturbance signal from the valuable signal of controlled variable.

With known disturbances spectral composition it is possible to design and develop digital LPF instead of analogue one. Its Nyquist frequency would be higher than the highest frequency in the disturbances spectrum. Such possibility appeared owing to market entry of cheap, effective, high-speed, 32bit microcontrollers with analogue signals sample rate of 30 kHz and higher.

The aim of this article is to divulge the case study of digital LPF design and its technical implementation using microcontroller and the powerful technology of MOMD [2].

LPF is inserted in the ACS feedback loop and, because of that, must match a range of requirements:

a) in the pass band amplitude-frequency characteristic (AFC) of the filter must be linear, i.e. transition coefficient of the filter be a constant;
b) filter must attenuate the disturbances and noises effectively in the rejection band, in the range of 50 – 80 dB;
c) in the low-frequency range, where ACS operates, the time delay of signal transmission through the filter must be minimal and phase-frequency characteristic must change gradually.

Apart from that, the attenuation coefficient of LPF transition function as a reaction to single step must be close to one.

Traditional approach for design and technical implementation of digital filters includes the following steps [3]:

a) analogue filter-prototype choosing and its parameters determination;
b) obtainment of the digital counterpart in the form of z-transfer function and recurrence expression which coefficients are calculated manually;
c) choosing a program package for LPF frequency characteristics analysis;
d) verification of ACS operability which has concerned LFP in its feedback loop;
e) composition of the program which calculates recurrence expression, e.g. in C programming language in Keil μVision environment;
f) compilation, debugging and uploading of the program to microcontroller;
g) testing of the filter technical implementation in the framework of the specific microcontroller.

This work takes specified knowledge and skill level from the developer and also a lot of time consumption if there is a necessity to test a couple of filter options with different parameters.

The alternative to traditional approach is model-oriented method of design (MOMD) of filters in MatLab environment [4]. Filter design and analysis (FDA) program package allows to automize a number of filter design stages. Developer chooses kind, type and order of the filter. For LPF cut-off frequency F_c, attenuation level in rejection band in dB and sample rate F_s are chosen. FDA package automatically generates filter, calculates its parameters, AFC, PFC, as shown in fig. 1.
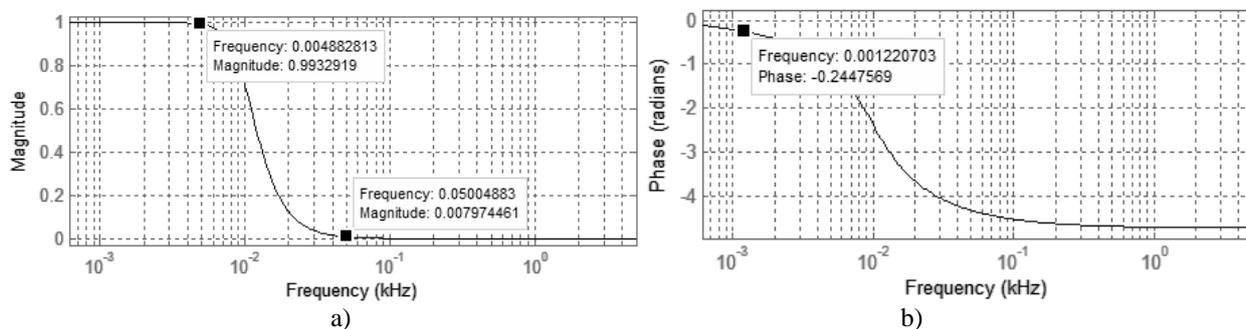

Fig. 1 a – AFC of the created filter with informative markers about pass band and level of attenuation of the industrial frequency; b – PFC of the created filter with informative markers about phase shift in the ACS operation frequency band

On this stage, using AFC, it is necessary to verify the linearity of the filter in the pass band, level of attenuation of high-frequency disturbances and noises, in particular, e.g. attenuation of the industrial frequency noises. Using PFC of the filter the

phase shift is determined in the ACS operation frequency band. It is important to check the filter reaction to single step or impulse inputs. This information is also granted by FDA package (see fig. 2).
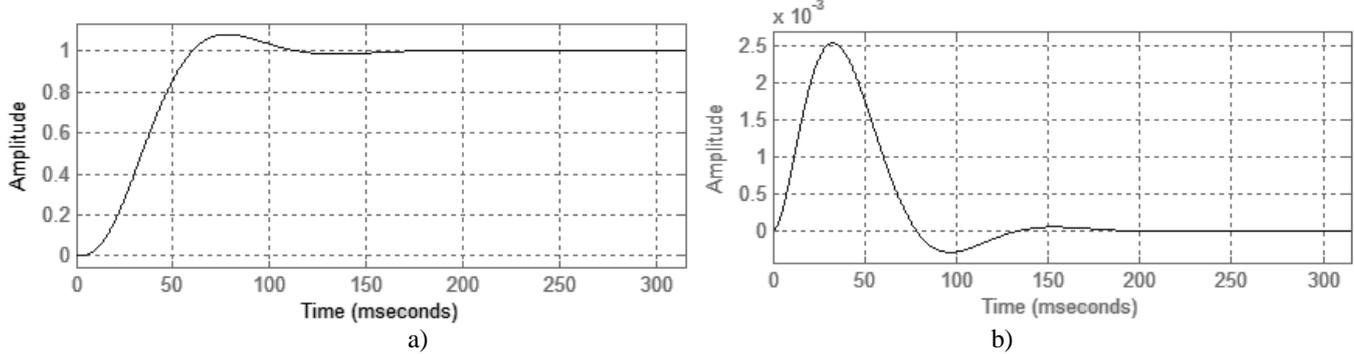

a)   b)

Fig. 2 – Digital LPF reactions when input is: a - step; b – impulse

It is rational to carry out analysis of couple of different filters options, summarizing in the table the main characteristics. The example of such table is provided below.

Table 1 - Comparative analysis of different orders of Butterworth LPF with cut-off frequency F_c=10Hz

Filter order	Pass band (Aout/Ain≥0,999), Hz	Attenuation on the frequency 50 Hz (Ain/Aout),	Phase shift on the frequency 1,22 Hz, rad
1	1,22	in 5 times	0,12
2	3,66	in 25 times	0,17
3	4,88	in 130 times	0,24
4	6,1	in 629 times	0,32

FDA package also allows to obtain coefficients of z-transfer function of the digital filter, e.g., for option № 3 from the table 1 transfer function has the following representation:

$$W(z) = \frac{1 + 2z^{-1} + z^{-2}}{1 - 1,935294z^{-1} + 0,939121z^{-2}} \cdot \frac{1 + z^{-1}}{1 - 0,939063z^{-1}} \cdot 2,9146 \cdot 10^{-5}$$

Similarly, this comparative research is applied to filters of other types and eventually chosen filter option can be exported from FDA to Simulink environment. The next step of design is to analyze the influence of the obtained digital LPF for stability and ACS quality of operation, because it is inserted in its feedback loop. As required, using optimization procedure, ACS controller parameters are being optimized. From the Simulink environment with additional package embedded coder [5] the model of the final filter is transferred to executable code, is compiled to uploadable hex-file of the microcontroller. Compilation is carried out automatically, without developer participation and there is no necessity to code. Nowadays there are a couple of dozens of different compilers for different microcontrollers platforms, in particular, in our example the package for STM32F4 Discovery debug module was used. This debug module has ARM Cortex-M4 architecture framework [6].

Created hex-file is then uploaded to microcontroller memory utilizing specific utility. After that technical implementation of the digital LPF can be tested by applying test signals to the debug module from the generator and checking the output signals with the oscilloscope. In this way, in the MatLab environment design of the digital LPF is carried out, as well as: verification of its workability in the ACS, generation and compilation of the program codes for chosen microcontrollers family. If, during balancing and commissioning or during ACS operation arises the necessity of digital LPF parameters change, than this operation can be done in a very short time. This is shown in the video presentation in [7]. MOMD also can be used during design of band pass or suppression filters for adaptive control systems and systems of technical diagnostics.

Conclusions
1. The technology of the model-oriented method of design allows to substantially reduce the time for design and development of the specific product without losing in quality during its design, because extensive possibilities of the MatLab environment are being used.
2. During model-oriented method of design mental activity of the developer is spent on comparative analysis of different filters options and their influence on ACS operation, meanwhile during traditional approach, the most of metal activity is spent on calculation of the filters coefficients and coding.

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A WORD IN DEFENSE OF THE DISCRETE CONTROL SIGNAL

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Abstract: In the structure of automatic regulators are still widely used astatic electrical constant speed actuators. An alternative solution is the use of electrical constant speed actuators, but the proportional action. The comparative evaluation of the both version of the actuators. Attention is drawn to the importance of determine the amount of time the full move electrical actuators. It is argued that the most accurate way to determine this is to use simulation modeling. The advantages obtained in case to ensure proportionality of the action of traditional electric constant speed actuator.

Key words: Automatic control system, simulation model, executive mechanism.

Introduction

Juergen Müller, the employee of Siemens, concerning influence of the actuation mechanism on the SAR loudspeaker has spoken quite definitely [4]: "In practice it often happens that the executive link has the greatest influence on a general characteristic of the site of regulation, and the regulator is mainly loaded by "correcting" the influence of an executive link. Unfortunately, at design often save on an executive link (that is in the false place), and "economy" on the equipment and then it is repeatedly eaten at installation and start in operation".

Keywords in this, quite long, the quote: **the regulator is mainly loaded by "correcting" the influence of an executive link.**

Unfortunately, the author haven't explained in what the reason of such **typical** situation and what actuation mechanisms so negatively influence on work of SAR. Therefore we will try to understand independently an origin oa a specified, urgent not only for Germany, problem.

To the middle of the 70th years in case of creation of SAR on the electrical automation equipment, in option of application of the linear algorithms of regulation, the electrical executive mechanisms (EEM) of constant speed equipped with asynchronous electromotors of an alternating current were used, as a rule. Such EIM type required use of an impulse width modulated signal of control. The matter is that on dynamic properties the specified EIM belong to astatic links. Moreover, they have a constant speed of movement–! Peculiar "payment"for it inevitable entering of distortions into a regulation algorithm was peculiar "board".

The beginning of application of such EIM belongs to the twentieth years of the last century. As requirements to quality of